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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION AT HIGH SUBSONIC SPEEDS OF A SPOILER-SLOT-DEFLECTOR COMBINATION ON AN NACA 65A006 WING WITH QUARTER-CHORD LINE SWEPT BACK 32.6°

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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION AT HIGH SUBSONIC SPEEDS OF A SPOILER-SLOT-DEFLECTOR COMBINATION ON AN NACA 65A006 WING WITH QUARTER-CHORD LINE SWEPT BACK 32.6°

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SUMMARY

An investigation was made in the Langley high-speed 7- by 10-foot tunnel through a Mach number range from 0.4 to 0.91 to determine the lateral control characteristics of a wing-fuselage combination with the wing quarter-chord line swept back 32.6°, an aspect ratio of 4, a taper ratio of 0.6, and an NACA 65A006 section. One wing panel was equipped with a 50-percent-semispan inboard spoiler-slot-deflector combination located between the 55- and 70-percent-chord lines.

As was previously found at low speed, the loss in rolling-moment effectiveness of an unvented spoiler at high wing angles of attack is materially reduced by the incorporation of a slot and deflector at Mach numbers up to 0.91. The optimum ratio of deflector to spoiler projection for best results varied with angle of attack, but a ratio of three-fourths to one gave appreciable rolling-moment effectiveness through the angle-of-attack range from 0° to 20°.

INTRODUCTION

The spoiler used as a lateral-control device has been the subject of considerable investigation at low and high speeds, and on both swept and unswept wings. Recent investigations of spoilers used as lateral-control devices have shown that on thin wings with small leading-edge radii the unvented spoiler loses effectiveness rapidly as the angle of attack is increased above about 8° (ref. 1). References 2 and 3 have shown that this loss in effectiveness at the higher angles of attack could be reduced by using a slot in the wing behind the spoiler that allowed the air to flow through the wing from the lower to the upper surface when the spoiler was deflected.

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The purpose of this investigation was to determine whether a slot plus a deflector is as effective at high subsonic speeds as it was at low speeds (refs. 2 and 4), and if so, to determine the ratio of deflector projection to spoiler projection for most beneficial results. The investigation was conducted in the Langley high-speed 7- by 10-foot tunnel through a Mach number range from 0.4 to 0.91 and at an angle-of-attack range from 0° to 20° except when limited by tunnel operating conditions. Rolling and yawing moments were obtained with spoiler alone, with slot plus deflector, and with spoiler-slot-deflector combination. Lift, drag, and pitching moments of the model were also obtained for the spoiler-slot-deflector combination.

SYMBOLS AND COEFFICIENTS

The forces and moments measured on the model are presented about an orthogonal system of axes. The longitudinal axis was parallel to the free-stream air flow and the vertical axis was in the vertical plane of symmetry. The origin of the axes was in the plane of symmetry at a longitudinal position corresponding to the projection of the quarter-chord point of the mean aerodynamic chord (fig. 1).

C_L	lift coefficient (Lift/qS)
C_D	drag coefficient (Drag/qS)
C_m	pitching-moment coefficient (Pitching moment/$qS\bar{c}$)
C_l	rolling-moment coefficient resulting from spoiler and/or deflector projection (Rolling moment/qSb)
C_n	yawing-moment coefficient resulting from spoiler and/or deflector projection (Yawing moment/qSb)
q	dynamic pressure, pounds per square foot $\left(\frac{\rho V^2}{2}\right)$
ρ	mass density of air, slugs/cu ft
V	free-stream air velocity, fps
S	wing area, 2.25 sq ft
b	wing span, 3.0 ft
c	local chord, ft
$\bar{c}$	mean aerodynamic chord of wing, 0.765 ft

M	Mach number
R	Reynolds number
α	angle of attack, deg
δ_s	spoiler projection, negative when projected from upper surface of wing, percent chord
δ_d	deflector projection, positive when projected from lower surface of wing, percent chord

APPARATUS AND MODEL

A drawing of the model and pertinent information are given in figure 1. The solid aluminum-alloy wing had NACA 65A006 airfoil sections parallel to the fuselage center line, a quarter-chord line swept back 32.6°, an aspect ratio of 4, and a taper ratio of 0.6. The lateral-control devices investigated included a spoiler, a slot-deflector combination, and a spoiler-slot-deflector combination (fig. 1). The slot consisted of an opening through the right wing between the 55- and 70-percent-chord lines extending spanwise from station 0.139b/2 to station 0.639b/2. In order to provide more strength in the wing, two chordwise ribs of metal were allowed to remain. For the plain-wing configuration, this slot was covered on the upper and lower surfaces of the wing with a 1/16-inch steel cover plate. Spoiler projections were obtained by raising the rear edge of the upper cover plate and bending the plate along the 55-percent-chord line. Deflector projections were obtained by lowering the forward edge of the plate on the lower surface of the wing and bending the plate along the 70-percent-chord line. The plates in the unprojected position were flush with the wing surfaces as were the edges attached to the wing in the projected positions.

The model was mounted on a sting-type support system in the Langley high-speed 7- by 10-foot tunnel. The sting was supported by a vertical strut downstream from the test section. The support system allowed the angle of attack of the model to be varied by rotating the model and sting in the vertical plane about an axis through the quarter-chord point of the wing mean aerodynamic chord. The forces and moments on the model were measured by means of electrical strain gages mounted inside the aluminum fuselage. The fuselage ordinates are presented in reference 1.

TESTS

Data were obtained at Mach numbers of 0.40, 0.80, 0.85, and 0.91, but since no unusual Mach number effects were apparent for Mach numbers

between 0.40 and 0.85, the basic data have been presented for only those two representative Mach numbers. However, rolling-moment coefficients are presented for additional Mach numbers. The angle-of-attack range was from 0° to 20° except for the higher Mach numbers where the maximum angle of attack was limited by tunnel choking conditions. The spoiler alone was tested through a projection range from 0 to -0.125c and the deflector alone from 0 to 0.10c. Various combinations of equal and unequal simultaneous projections of spoiler and deflector with slot open were tested.

The variation of test Reynolds number with Mach number based on the mean aerodynamic chord is given in figure 2.

CORRECTIONS

The test data have been corrected for jet-boundary effects by the method given in reference 5. Blockage corrections based on the model with plain wing as determined from reference 6 to account for the constriction effects of the model on the tunnel free-stream flow were applied to the data. The drag has been corrected by an increment obtained by adjusting the pressure at the base of the fuselage to equal free-stream static pressure. No corrections for wing bending or twisting have been applied since corrections as calculated from static loads on the wing before the slot was cut were found to be small for the bending and negligible for the twisting of wing.

RESULTS AND DISCUSSION

The variation of lateral control characteristics with angle of attack for various projections of the spoiler alone is given in figure 3. The rolling moments produced by the spoiler in this investigation are considerably smaller than those given in reference 1 for the same spoiler span and projection. This difference in effectiveness as recorded in the two investigations is caused mainly by the manner in which the projection was obtained as proved by unpublished results of later tests. Maximum spoiler effectiveness is obtained when the spoiler is approximately perpendicular to the wing surface. In this investigation, projection was obtained by raising the trailing edge of the spoiler in an operation very similar to the operation of a split flap. Except for this difference in size of the rolling-moment coefficient the spoiler in this investigation had characteristics very similar to the one in reference 1. The rolling-moment coefficient decreased rapidly above an angle of attack of 8°, becoming zero or slightly negative at 16° and above.

A recent low-speed ($M \approx 0.3$) investigation on a 45° sweptback, 6-percent-thick wing showed that some of the spoiler loss in effectiveness at high angles of attack could be eliminated by means of a slot and deflector (ref. 2). Figure 4 shows the effect on rolling-moment coefficients of a slot and deflector without a spoiler. The figure clearly shows the slot-deflector combination to be generally more effective at the higher angles of attack than at the lower angles except for small projections of the deflector. The results obtained by combining the spoiler with the slot and deflector are shown in figure 5. Various ratios of deflector projection to spoiler projection were investigated. Some of these projection ratios were more effective than others, but almost all of them showed some effectiveness throughout the angle-of-attack range.

The yawing-moment characteristics were very similar for spoiler alone, slot-deflector combination, and combination of spoiler, slot, and deflector (figs. 3 to 5). They were positive or favorable at the lower angles of attack and usually small and unfavorable at the higher angles of attack.

Because the tests of the spoiler-slot-deflector combination are considered the ones of more importance, the lift, drag, and pitching-moment data of those tests along with the plain wing data are presented in figure 6. The larger projections of the spoiler and deflector produced increments of positive pitching moment, but none of the projections caused any significant change in stability as measured by the slope of the pitching-moment curve, except the maximum projection at the higher Mach number. The lift data indicate that the loss in lift is a function of the amount of spoiler-deflector projection, the ratio of spoiler projection to deflector projection, and the angle of attack. The drag coefficients generally increased with increased projection of spoiler and deflector. The drag coefficient of the spoiler-slot-deflector combination is much greater than that of the spoiler alone at low angles of attack (fig. 7), but at angles of attack of 8° and above, the drag coefficients of the two configurations are essentially the same, although the spoiler-slot-deflector combination produces much greater rolling-moment coefficients.

Figure 8 shows the effect on rolling-moment coefficient of varying the deflector projection while holding the spoiler at a given projection. The given projections of the spoiler are $-0.05c$ and $-0.10c$. The figure shows that for angles of attack up to 8°, the maximum rolling-moment coefficients are obtained by a deflector projection equal to one-half the spoiler projection, but for angles of attack above 8° best results are obtained with deflector projection about equal to spoiler projection. Since there is considerable loss in effectiveness at zero angle of attack for a ratio of deflector projection to spoiler projection of 1.0 to 1.0, a ratio of 0.75 to 1.0 is probably the most advantageous throughout the angle-of-attack range.

The rolling-moment data of figure 9 show that the rolling effectiveness of the spoiler-slot-deflector combination with the spoiler and deflector projections numerically equal is nonlinear over the projection range but generally increases with increase in projection.

CONCLUSIONS

A wind-tunnel investigation was made through a Mach number range from 0.40 to 0.91 to determine the lateral control characteristics of a wing-fuselage combination equipped with a flap-type spoiler hinged at the 55-percent-chord line; a deflector hinged at the 70-percent-chord line, and a slot in the wing between the two hinge lines. The span of the controls was 50 percent of the wing semispan and the control was located inboard on the right wing. As a result of the investigation the following conclusions are made:

1. As was previously found at low speeds, a spoiler-slot-deflector combination is effective in producing rolling moments over a greater angle-of-attack range than an unvented spoiler alone at Mach numbers up to 0.91.

2. The optimum ratio of deflector projection to spoiler projection for rolling-moment effectiveness varies with angle of attack, but a ratio of 0.75 to 1.0 gives appreciable effectiveness through the angle-of-attack range from 0° to 20°.

3. A deflector and slot without a spoiler is also effective in producing rolling moments at high angles of attack.

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3. Hammond, Alexander D., and Watson, James M.: Lateral-Control Investigation at Transonic Speeds of Retractable Spoiler and Plug-Type Spoiler-Slot Ailerons on a Tapered 60° Sweptback Wing of Aspect Ratio 2. Transonic-Bump Method. NACA RM L52F16, 1952.

4. Wenzinger, Carl J., and Rogallo, Francis M.: Wind-Tunnel Investigation of Spoiler, Deflector, and Slot Lateral-Control Devices on Wings With Full-Span Split and Slotted Flaps. NACA Rep. 706, 1941.

5. Gillis, Clarence L., Polhamus, Edward C., and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7- by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Formerly NACA ARR L5G31.)

6. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, With Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Supersedes NACA RM A7B28.)

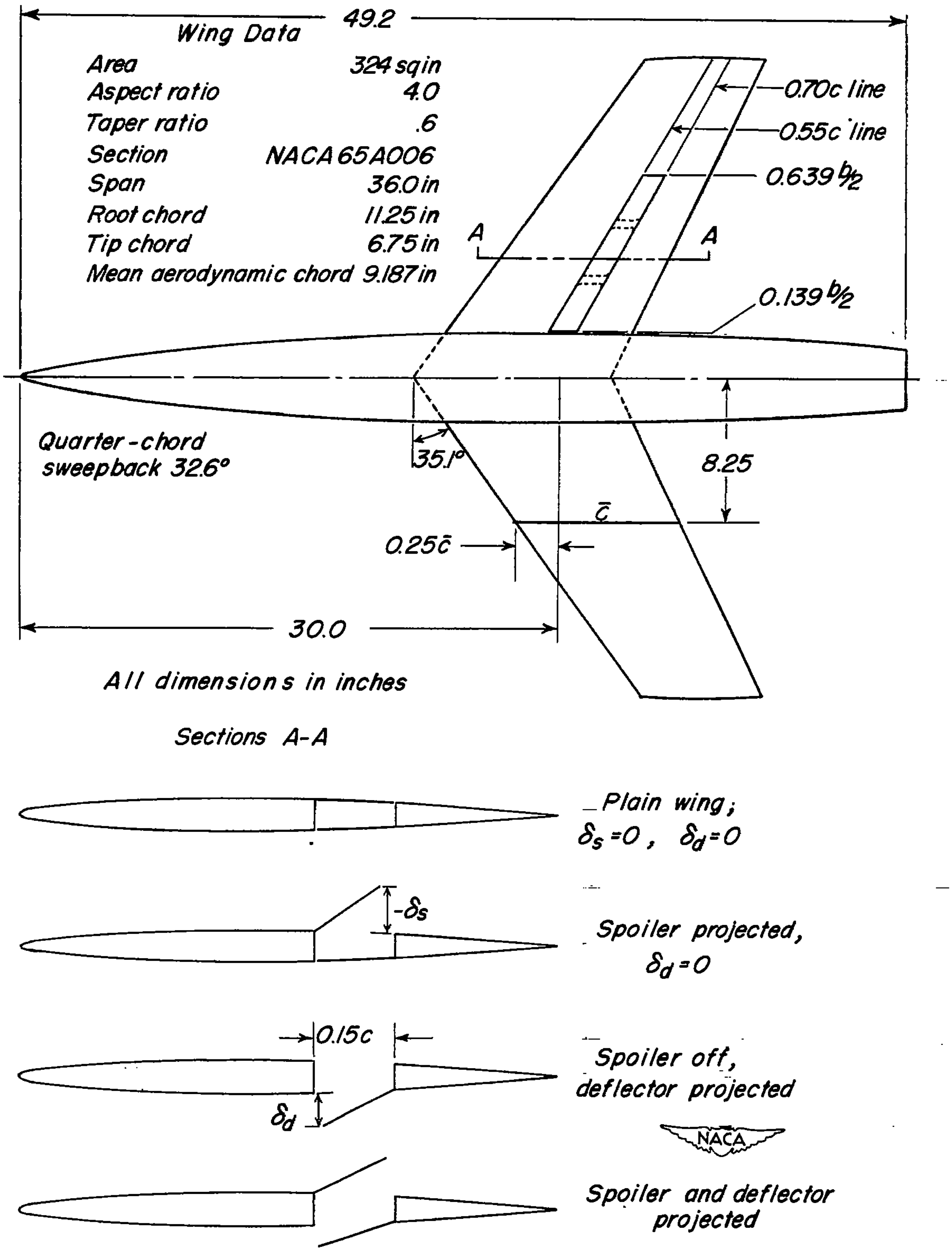

Figure 1.- General arr[redacted]del and controls.

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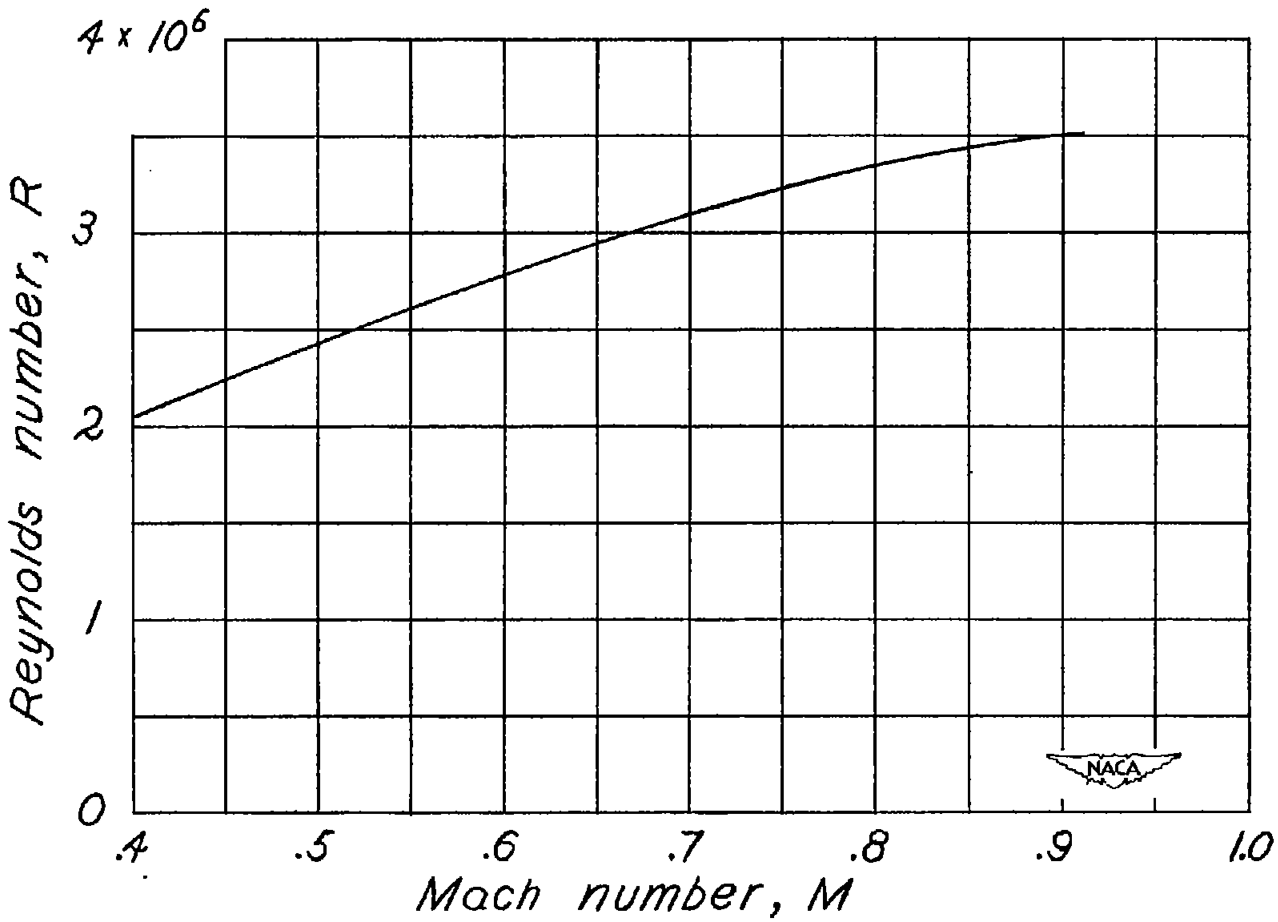

Figure 2.- Variation of Reynolds number with Mach number.

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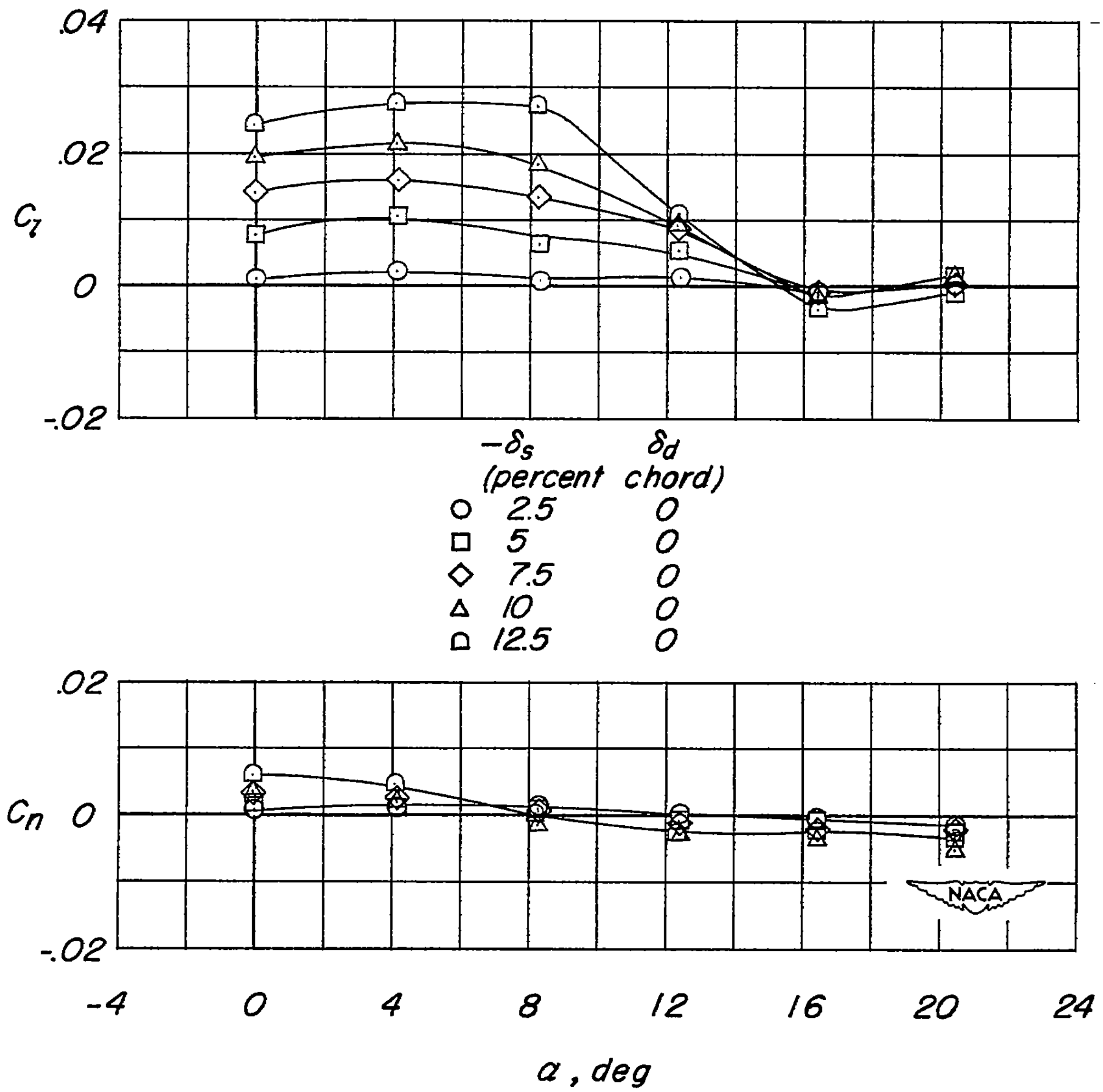
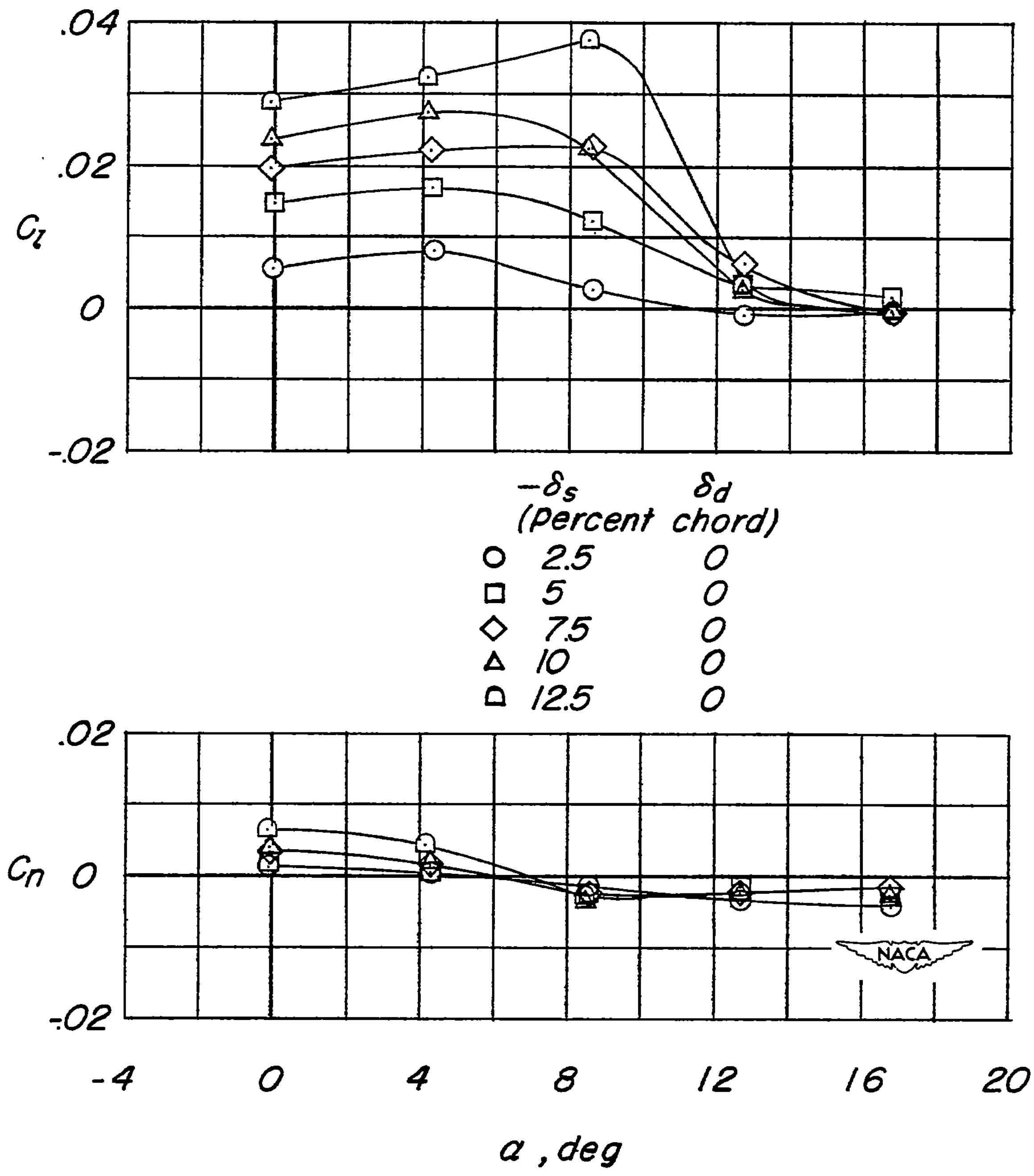


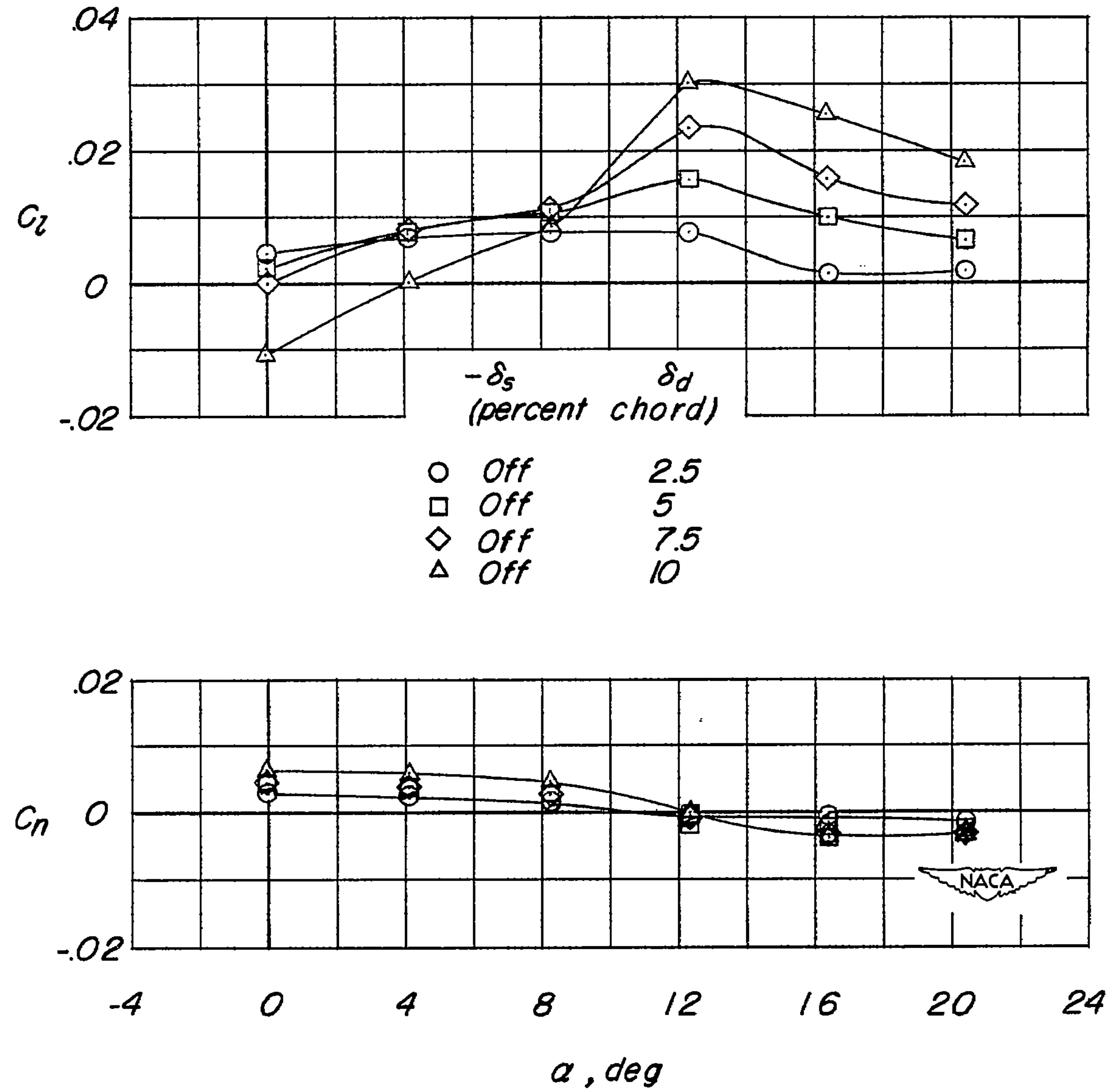
(a) M = 0.40.

Figure 3.- Variation of lateral control characteristics with angle of attack for various projections of the spoiler alone with slot closed.



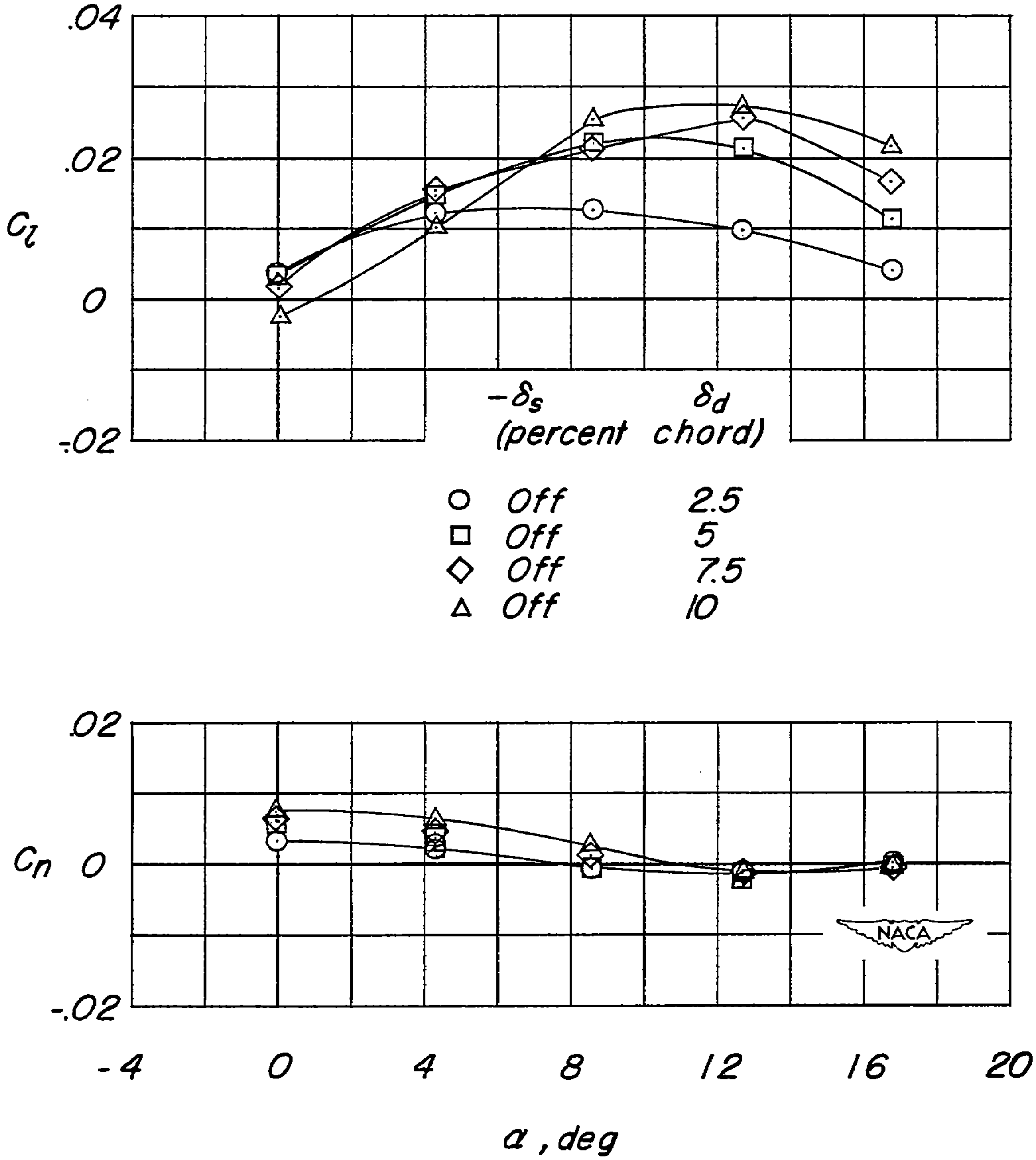
(b) M = 0.85.

Figure 3.- Concluded.



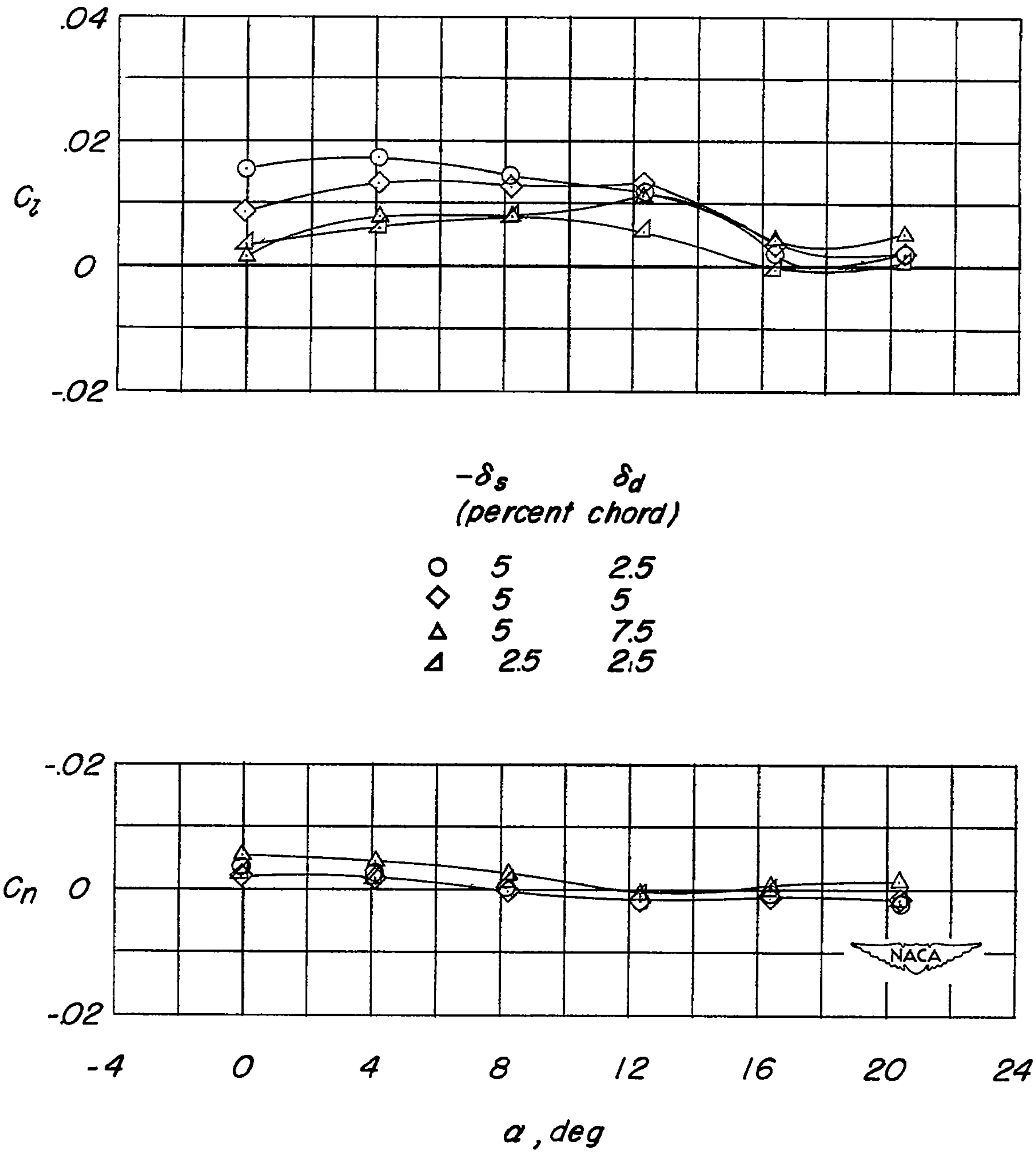
(a) M = 0.40.

Figure 4.- Variation of lateral control characteristics with angle of attack for various projections of the deflector with slot open and spoiler off.



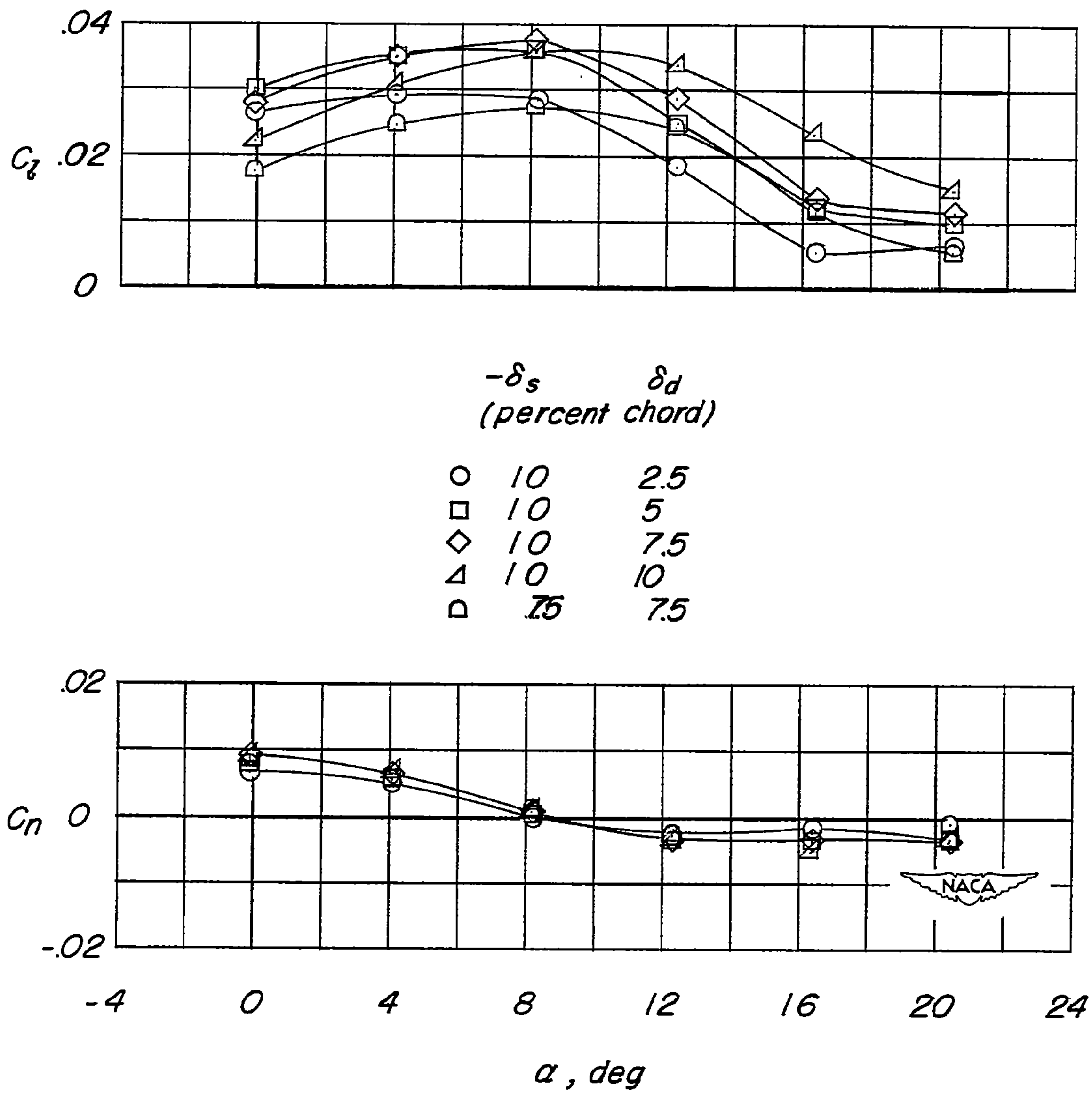
(b) M = 0.85.

Figure 4.- Concluded.



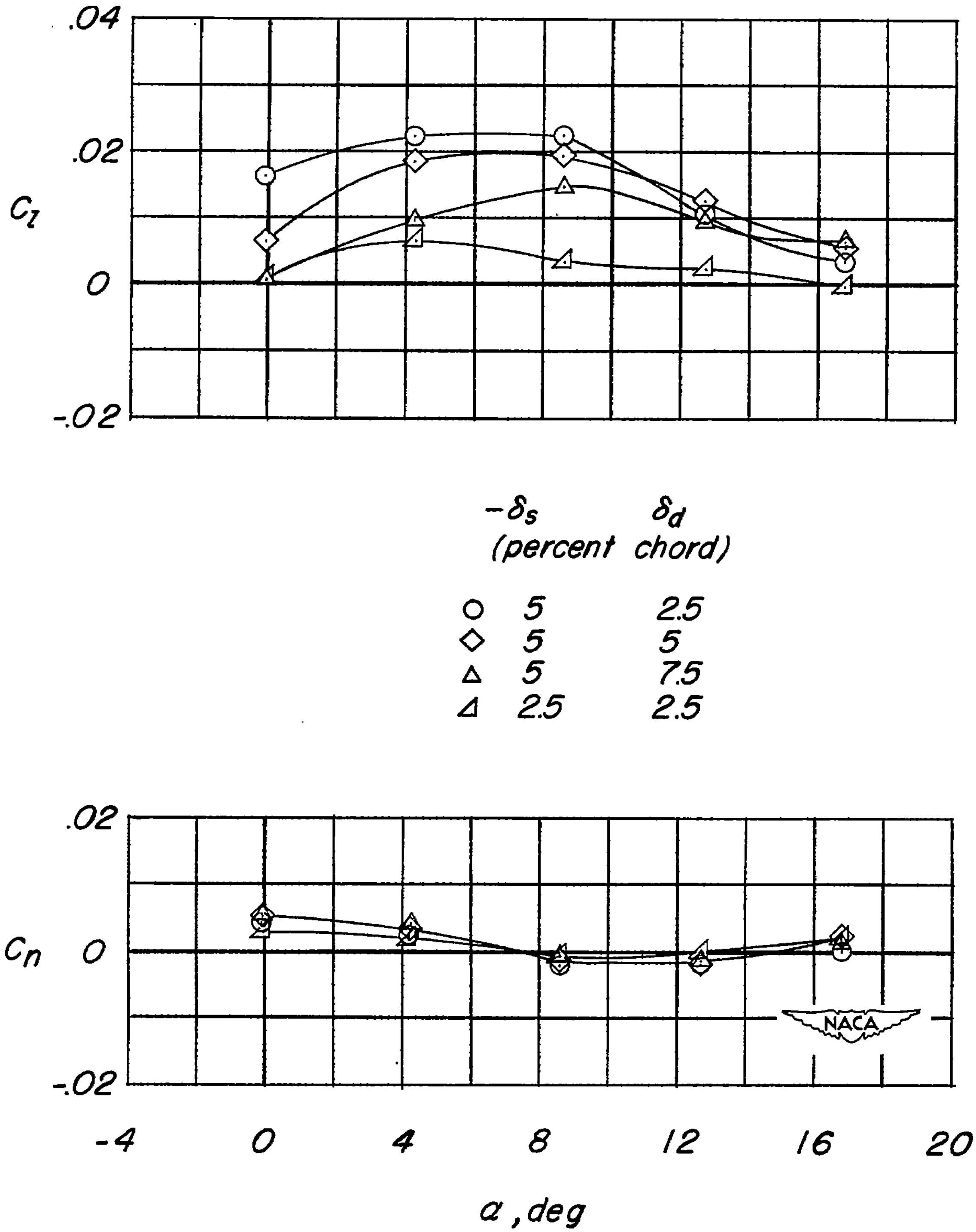
(a) M = 0.40.

Figure 5.- Variation of lateral control characteristics with angle of attack for various projections of the spoiler-slot-deflector combination.



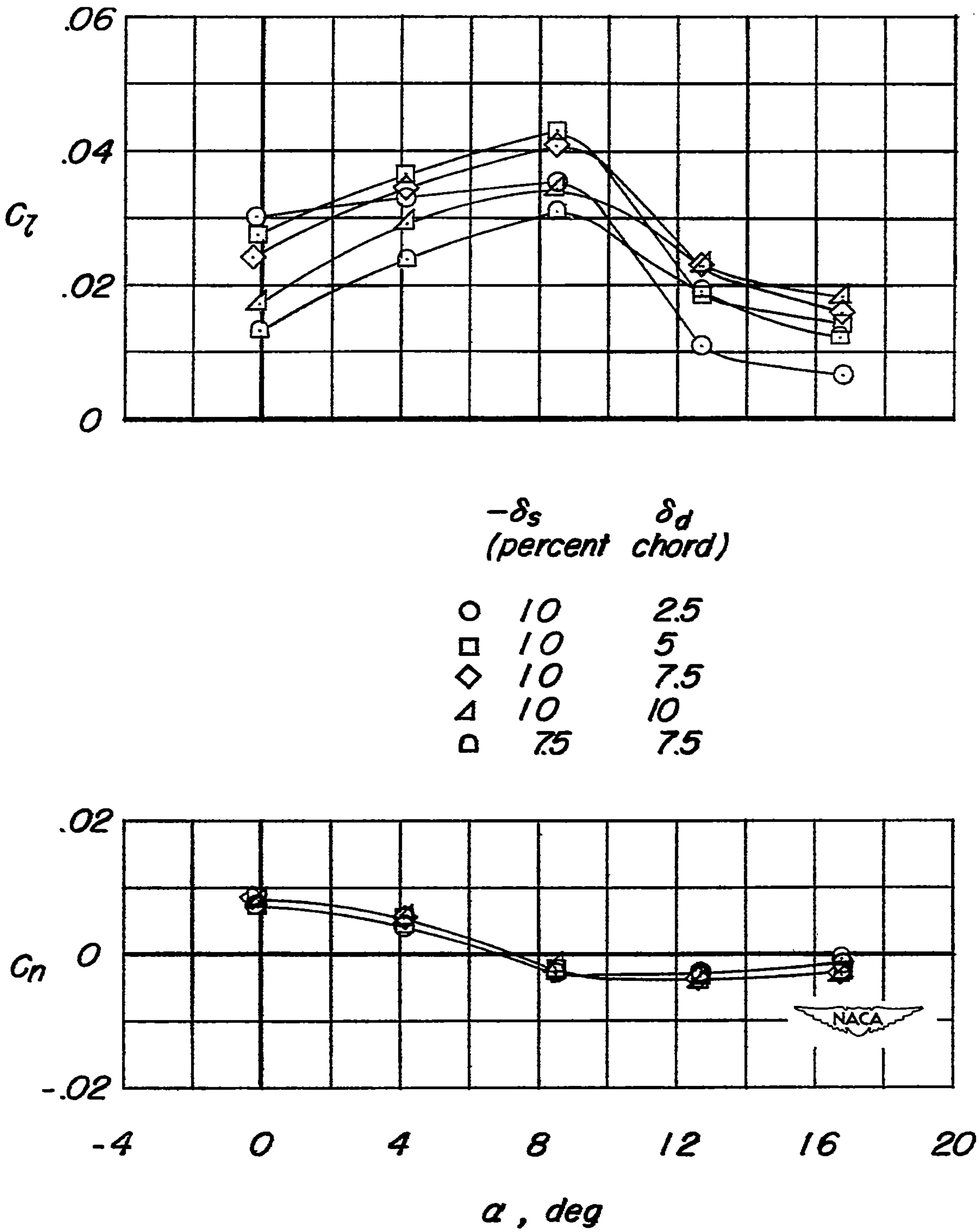
(a) M = 0.40. Concluded.

Figure 5.- Continued.



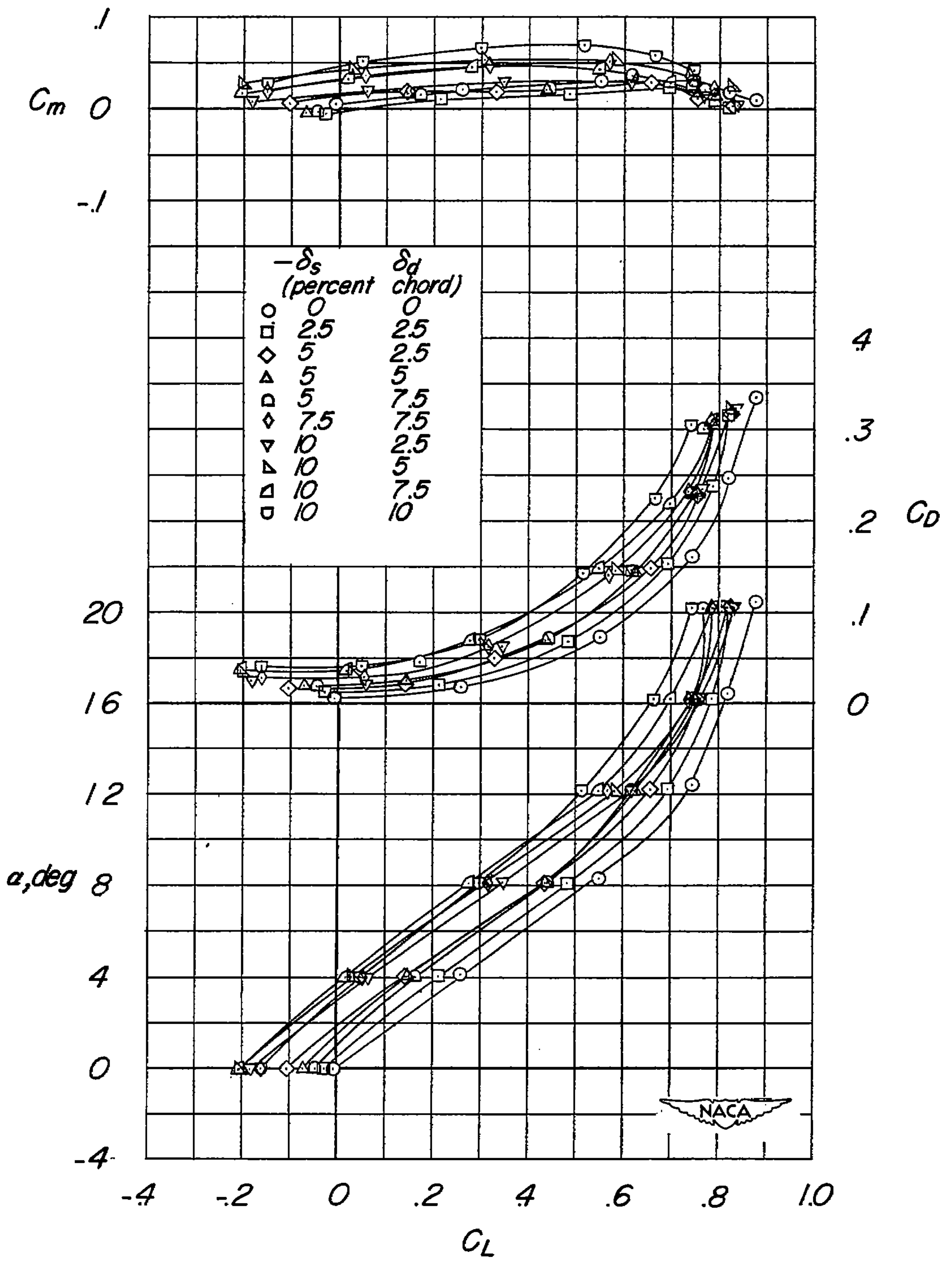
(b) M = 0.85.

Figure 5.- Continued.



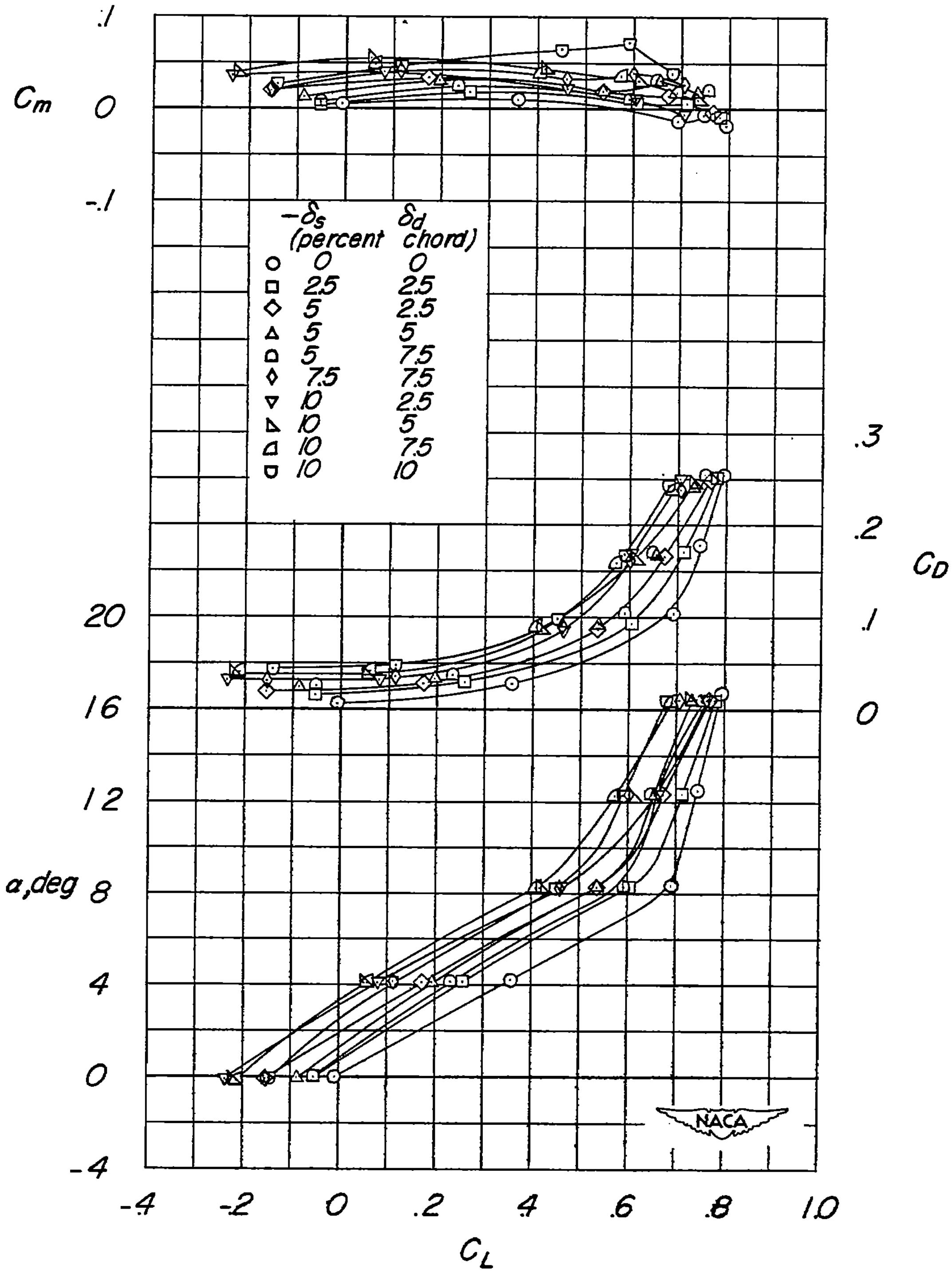
(b) M = 0.85. Concluded.

Figure 5.- Concluded.



(a) M = 0.40.

Figure 6.- Effect of spoiler and deflector projections with slot open on the aerodynamic characteristics in pitch.



(b) M = 0.85.

Figure 6.- Concluded.

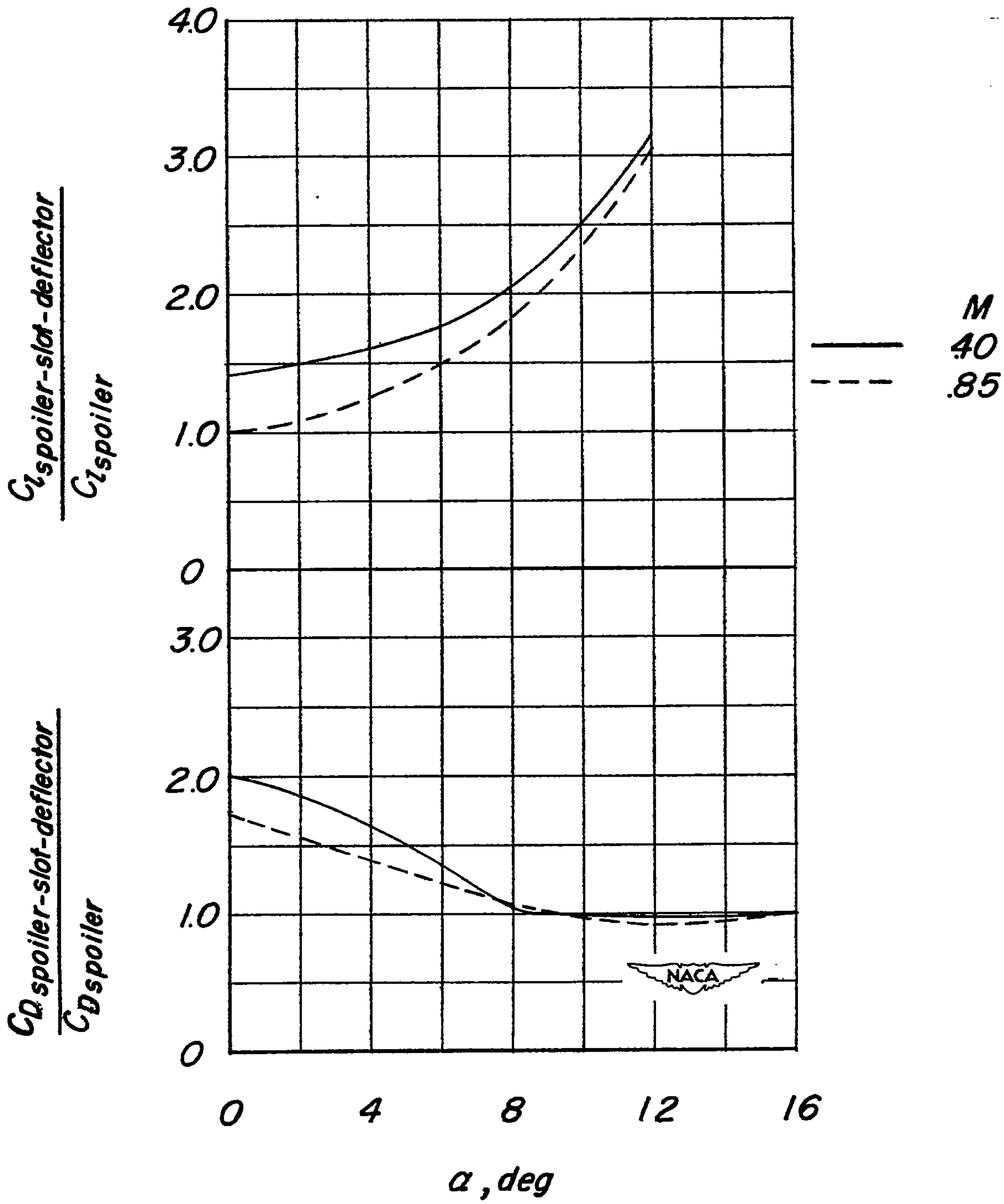


Figure 7.- Ratio of drag and rolling-moment coefficients of spoiler-slot-deflector combination to that of spoiler alone at various wing angles of attack. δ_s = -10 percent chord, δ_d = 7.5 percent chord.

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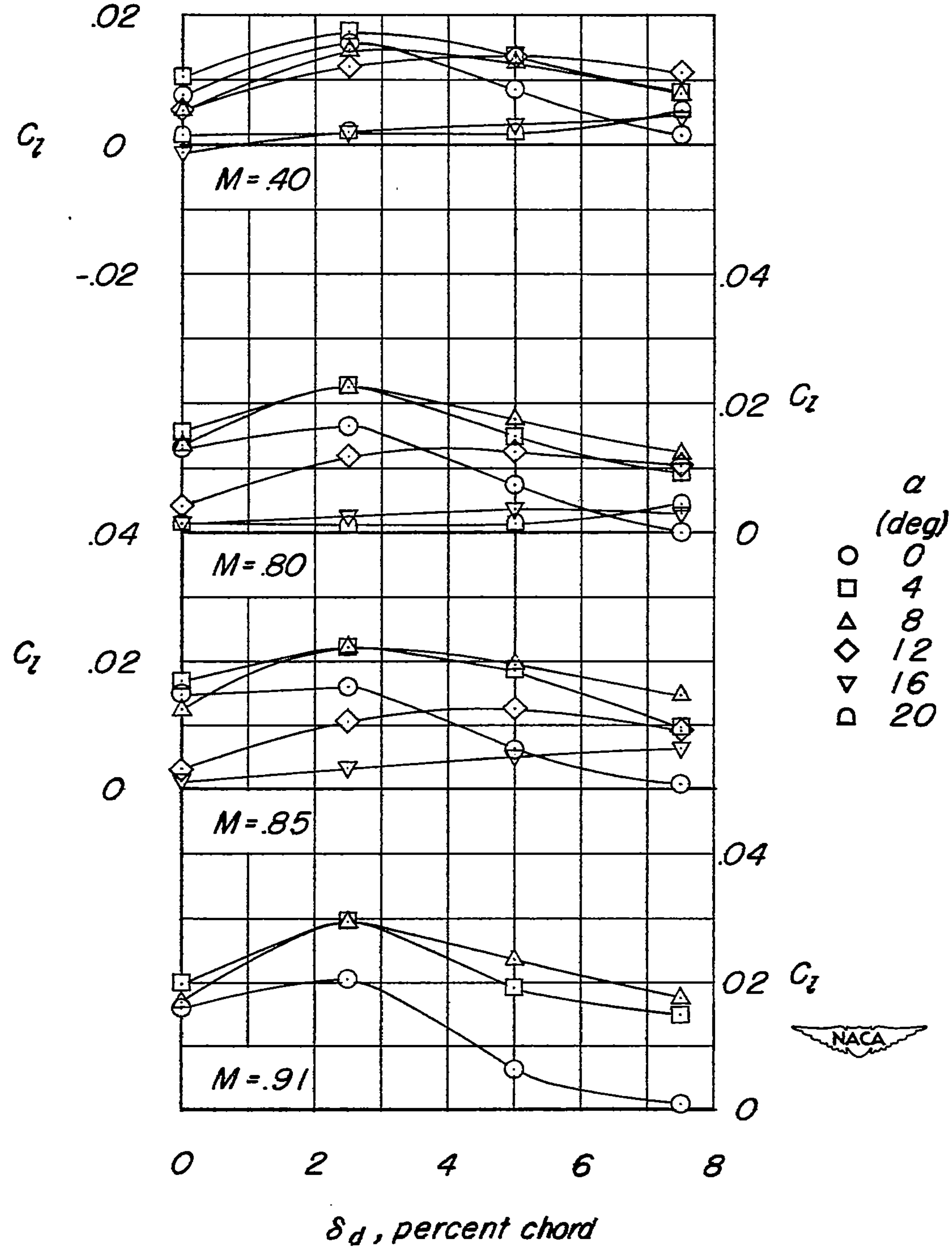
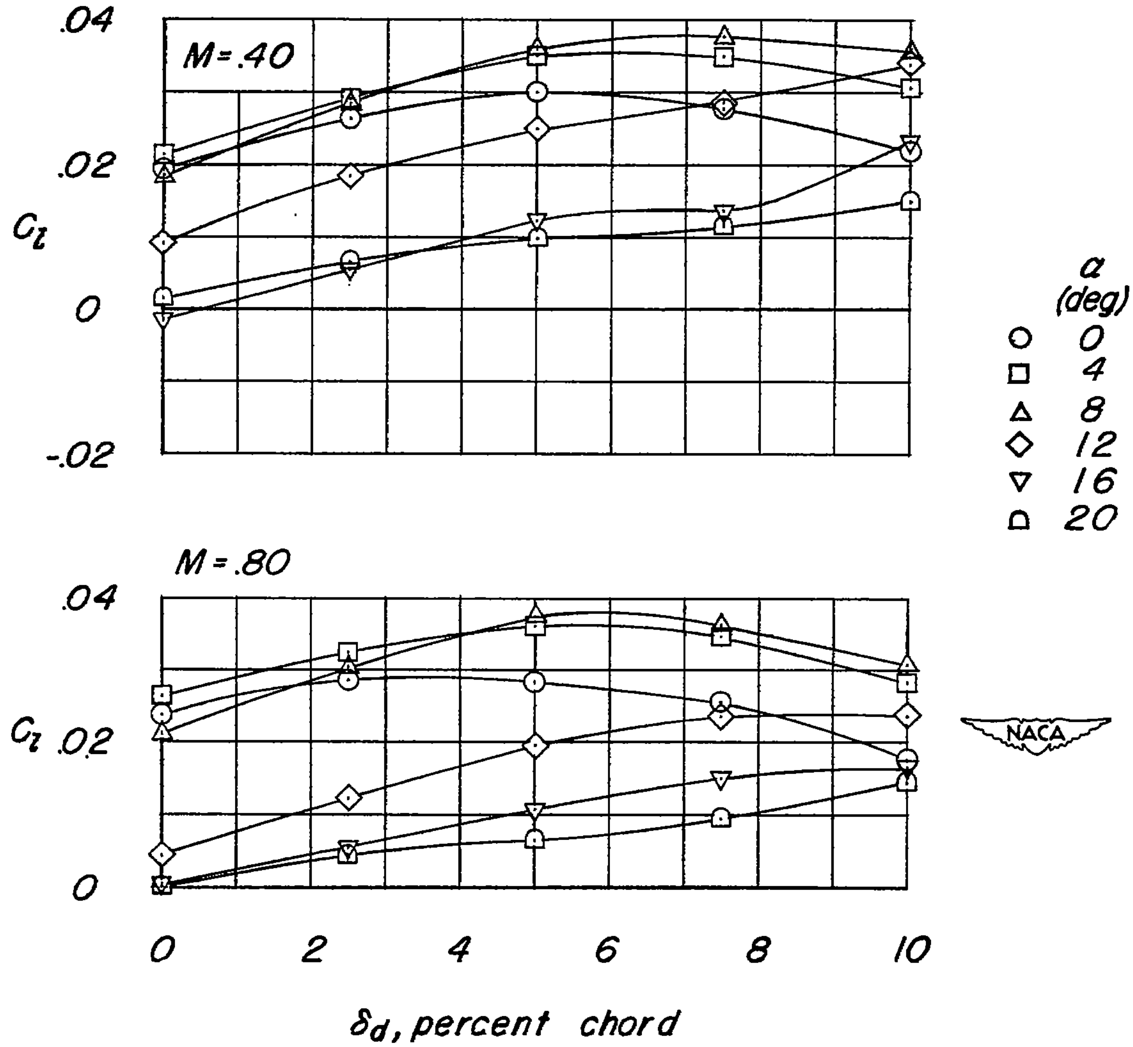


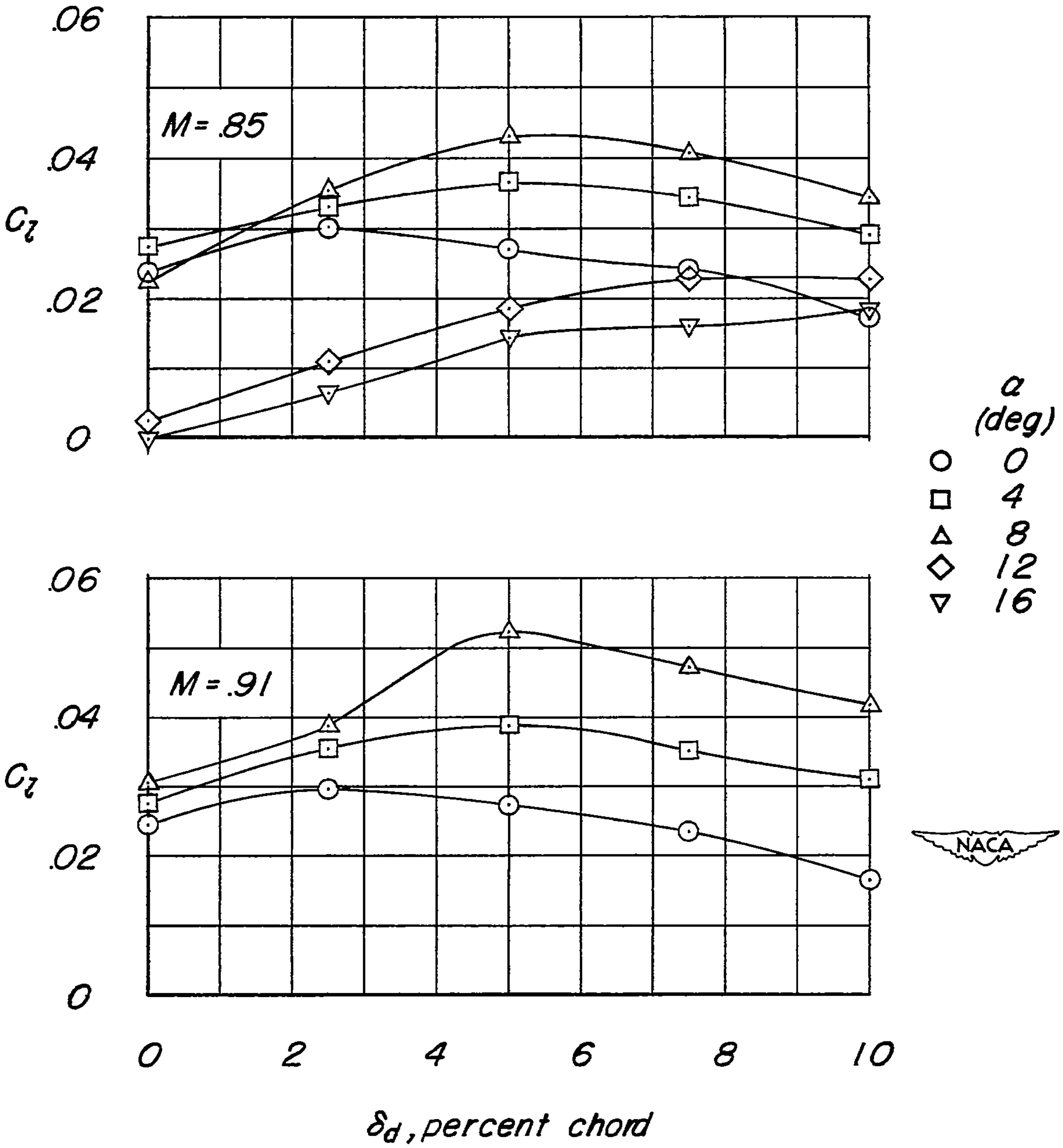
(a) δ_s = -5 percent chord.

Figure 8.- Effect on the rolling-moment coefficient of various ratios of deflector projection to spoiler projection for the spoiler-slot-deflector combination at various wing angles of attack.



(b) δ_s = -10 percent chord.

Figure 8.- Continued.



(b) δ_s = -10 percent chord. Concluded.

Figure 8.- Concluded.

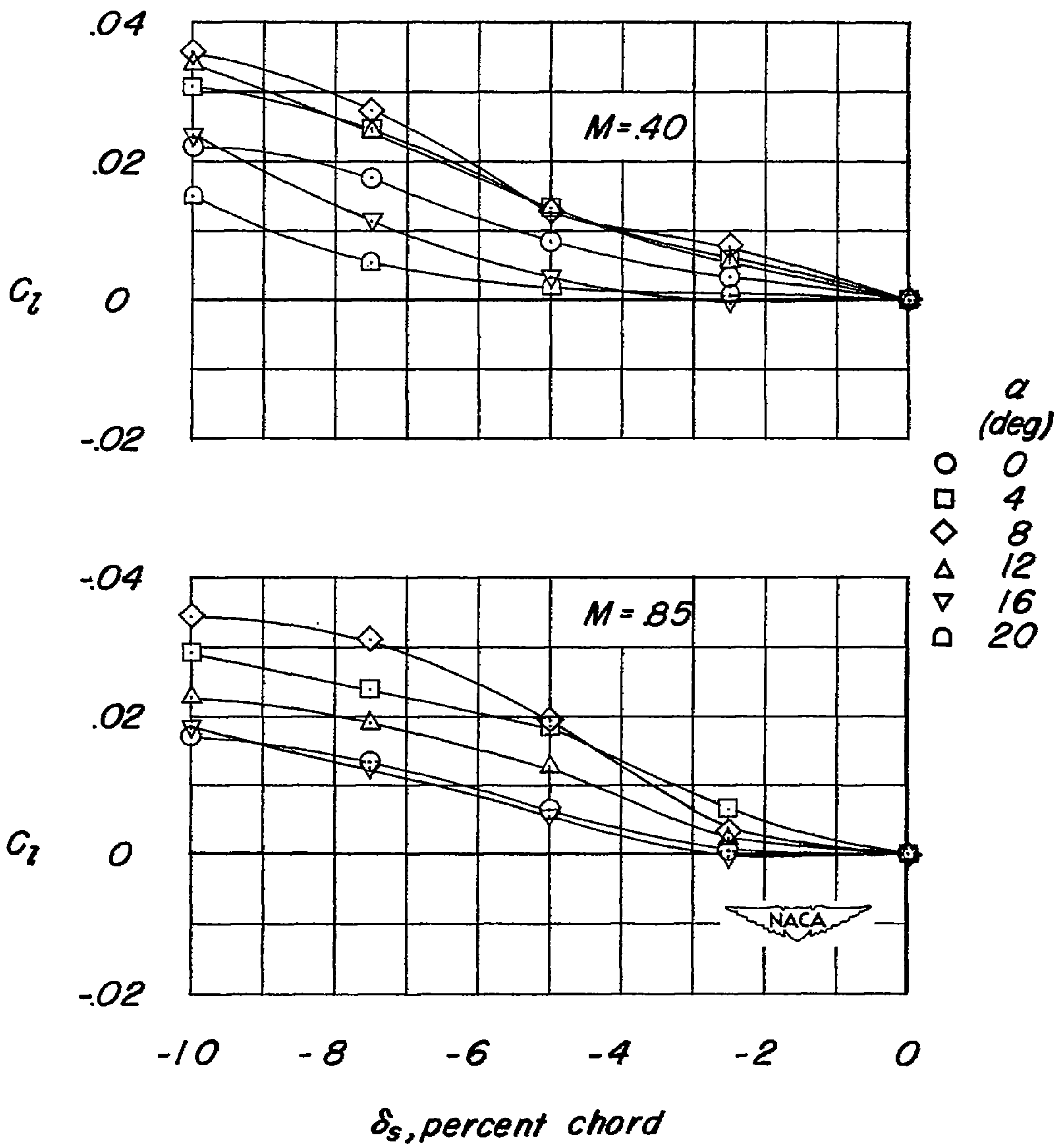


Figure 9.- Variation of rolling-moment coefficient with combined projections of deflector and spoiler in 1.0 to 1.0 ratio for the spoiler-slot-deflector combination. $\delta_s = -\delta_d$.